

# Phenolic compounds and fatty acid composition of organic and conventional grown pecan kernels

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## Abstract

**BACKGROUND:** In this study, differences in contents of phenolic compounds and fatty acids in pecan kernels of organically versus conventionally grown pecan cultivars (Cheyenne, Desirable, and Wichita) were evaluated.

**RESULTS:** Although nine phenolic compounds (gallic acid, catechol, catechin, epicatechin, *m*-coumaric acid, chlorogenic acid, ellagic acid, caffeic acid and an ellagic acid derivative) were identified in the methanol extract (80% methanol) of defatted kernels, only three compounds (gallic acid, catechin and ellagic acid) existed in sufficient amounts to accurately quantify levels in different cultivars and to study differences in organic versus conventional cultivation. Levels of ellagic acid and catechin found in organically grown 'Desirable' were fourfold and twofold higher than in conventional samples, respectively. Furthermore, significant differences in these two compounds were also observed when comparing values between cultivars. Oil content was also significantly greater only in organically grown 'Desirable'. Oleic acid was the major fatty acid present and its content was significantly higher in organically versus conventionally grown 'Desirable' pecans, while there was no difference in levels of oleic acid in 'Wichita' and 'Cheyenne'. On the other hand, linoleic acid content was significantly less in organically versus conventionally grown 'Desirable' pecans.

**CONCLUSION:** Overall, these results showed that the effects of cultural differences (i.e. organic versus conventional cultivation) on kernel composition largely depend on the type of pecan cultivar.

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**Keywords:** phenolic compounds; fatty acids; pecan cultivars; organic cultivation; conventional cultivation

## INTRODUCTION

Traditional intensive agriculture aimed at maximal productivity utilizing high inputs of fertilizers and pesticides is now being blamed for decline in soil fertility and adverse effects on the environment.<sup>1</sup> Organic farming was proposed as an alternative for sustainable agriculture about 50 years ago and is now gaining widespread momentum for being friendly to the environment and for producing more nutritious food for human health.<sup>2</sup> It is unlikely that American or Western diets could create deficiencies in protein, carbohydrates or vitamins, so the argument in favor of organic foods has to be based on secondary metabolites such as phenolic compounds.<sup>3</sup> It has been suggested that by using organic cultivation methods environmental stress on the plant may increase, resulting in accumulation of inducible, protective secondary metabolites.<sup>4,5</sup>

There are over 5000 species of phenolic compounds in plants.<sup>6</sup> These compounds are not only responsible for color, aroma and taste of the food, but also are frequently related to health benefits of foods. For example, phenolic compounds have been reported to protect against atherosclerosis, hypertension, cardiovascular diseases, cancer and viral infections, and to act as antidepressants and general antioxidants.<sup>7–9</sup> Phenolic

phytochemicals are potent antioxidants that have an important role as preventive agents against oxidative stress.<sup>10</sup> Recent studies have evaluated antioxidant capacities of various nuts and have reported a positive correlation between phenolic compound concentration and antioxidant activity.<sup>11–14</sup> Among the phenolic compounds possessing antioxidant activity found in various types of nuts, catechins,<sup>15</sup> hydroxybenzoic acids,<sup>16</sup> and tannins<sup>11,17</sup> appear to be common.

Wu *et al.*<sup>18</sup> reported the lipophilic and hydrophilic antioxidant capacities of common food in the USA. This study entailed

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analysis of several foods including fruits, vegetables, spices, cereals, and nuts. Within the nut category, pecan kernels exhibited the highest total extractable phenolic content and antioxidant activity. Ellagic acid is a major component of phenolic compounds in pecan kernels.<sup>11</sup> Ellagic acid is a powerful antioxidant and has been implicated in controlling blood pressure, cancers and viral infections.<sup>19–21</sup>

For the reasons described above, organic foods are perceived by consumers to be more nutritious, and hence the market for organically cultivated foods has grown 20–25% annually and is projected to surpass US \$22 billion by 2010.<sup>22–24</sup> Thus organically grown foods are being produced and promoted as being friendlier to the environment and healthier for the consumer. However, it is not known whether there are chemical differences between organically grown and conventionally grown foods such as pecan. The present study was therefore conducted to evaluate differences between phenolic compounds in organically and conventionally grown pecan cultivars (Cheyenne, Desirable and Wichita). Fatty acid composition was also included in the study because pecans are rich in lipid and a difference in fatty acid composition of organically *versus* conventionally produced olive oil has been reported previously.<sup>25</sup>

## MATERIALS AND METHODS

### Cultivation and sampling of pecans

Three pecan cultivars (Cheyenne, Desirable and Wichita) were grown following conventional or organic cultural practices for 7 years at Gerbert Orchard in Carlton, Texas. The test site consisted of 8.1 ha of land where soils for both conventionally and organically grown areas varied from sand to clay loam. There were 87 trees ha<sup>-1</sup> in both conventional and organic orchards. The conventional orchard was given three applications per year (February, June and September) of 56 kg ha<sup>-1</sup> of nitrogen as ammonium sulfate, while the organic farm was given three applications of poultry litter at a rate of 44.8 kg ha<sup>-1</sup> of effective nitrogen. The yearly rainfall at the test site is given in Table 1. Trees were drip-irrigated at a rate of 94.1 mm ha<sup>-1</sup> on occasions when there was not enough rain. For pest control in the organic orchard, beneficial insects, such as *Trichogramma* sp. wasps and lacewings (*Chrysopa* sp.), were released to control pecan case bearer (*Acrobasis nuxvorella* Neunzig) and aphids (black pecan aphid (*Melanocallis caryaefoliae* Davis), black-margined aphid (*Monellia caryella* Fitch) and yellow pecan aphid (*Monelliopsis pecanis* Bissell)). In the conventional orchard, chemical pesticides were applied for pest control according to the recommendations of Texas AgriLife Extension.<sup>26</sup> Fruits were collected from three randomly selected trees of each cultivar from both the conventional and organic orchards. After harvest, fruits were transported to the laboratory and mechanically

cracked. After removal of rotten and necrotic kernels, healthy pecan kernels were stored at –80 °C and then separately analyzed for different biochemical measurements described below.

### Chemicals

Solvents (HPLC grade) were purchased from Fisher Scientific (Houston, TX, USA). Gallic acid and catechin standards, and Sephadex LH-20 were purchased from Sigma Chemical Co. (St Louis, MO, USA). Ellagic acid and oleuropein standards were obtained from Extrasynthese (Genay, France).

### Pecan sample preparation

Frozen kernels were pulverized in liquid nitrogen using a mortar and pestle. Kernel powder was then defatted with hexane (1:20) (w:v) using an Ultraturrax T25 homogenizer (IKA Works, Wilmington, NC, USA). After homogenization, samples were centrifuged at 30 100 × g for 45 min. Supernatant was filtered with a Buchner funnel and slow filtration rate filter paper (Fisher 09-801F, Fisher Scientific, Houston, TX, USA). The cake was defatted two more times, the hexane fractions were pooled and the remaining powder was dried overnight at room temperature. The powder was flushed with nitrogen and stored in a sealed container at –80 °C until analysis. Pecan oil was obtained after evaporating pooled hexane fractions with a rotavapor at 35 °C under vacuum. The oil was weighed, flushed with nitrogen and stored at –80 °C until analysis.

### Extraction of free phenolic compounds

A sample of 3 g of frozen defatted pecan kernel powder was extracted using 12 mL of 80% aqueous methanol by blending in a polytron (Brinkmann model PT 3100, Fisher Scientific) at maximum speed for 30 s (three times at 10 s intervals). The mixture was centrifuged at 30 100 × g for 30 min. After centrifugation the supernatant was removed and the pellet was re-extracted with 12 mL of 80% aqueous methanol. The extracts were pooled and concentrated by rotavapor to 2 mL at 45 °C. Extracts were filtered through a 0.45 µm syringe filter and further concentrated using an SPD 1010 SpeedVac (Thermo Savant, Holbrook, NY, USA). The final volume was adjusted to 500 µL by adding Milli-Q water. Extracts were stored at –20 °C until further analysis.

### LH-20 Chromatography

Three subsamples of each methanolic extract from three replicate trees were subjected to LH-20 chromatography. Briefly, 750 mg of Sephadex LH-20 was conditioned with 80% aqueous methanol overnight and the slurry was poured into a 9 mm × 100 mm column and allowed to settle for 1 h undisturbed. The column was washed with 10 mL of 80% methanol. The mobile phase was passed through the resin at 0.5 mL min<sup>-1</sup> flow rate before loading the extract. An aliquot of extract (300 µL) was loaded on top of the LH-20 column. The column was eluted with 10 mL of 80% methanol and 2 mL fractions were collected. Fractions were concentrated using a SpeedVac, volume was adjusted to 500 µL using milli-Q water and analyzed by high-performance liquid chromatography (HPLC) for phenolic compound composition.

### High-performance liquid chromatography

Chromatographic separations of phenolic constituent of pecan methanolic extracts were performed by means of a Waters (Milford, MA, USA) Alliance 2695 HPLC system equipped with a 2996

**Table 1.** Hamilton county annual rainfall: USDA Farm Service Agency

Year	Annual rainfall (mm)
2002	860.29
2003	791.97
2004	1247.64
2005	539.75
2006	596.29
2007	1217.67
Average	874.52

photodiode array detector. Phenolic compounds were separated using a Waters XTerra MS C<sub>18</sub> (5 µm particle size) column (3.9 mm × 150 mm) maintained at 35 °C. The column was eluted at a flow rate of 1 mL min<sup>-1</sup> and a gradient bisolvent system consisting of 0.02% trifluoroacetic acid in water (solvent A) and 100% acetonitrile (solvent B). Initial composition of gradient was comprised of 95% A and 5% B, followed by a linear decrease of A to 90% in 10 min. After 10 min solvent A was further decreased to 80% in 22 min and finally to 70% solvent A in 30 min. The column was equilibrated at 95% solvent A for 10 min before each run. A 20 µL sample was injected into the HPLC system for analysis and elution profiles were detected at 280 nm using the photodiode detector. Gallic acid, catechin, ellagic acid, oleuropein (as internal standard) and other trace phenolic compounds were identified by matching retention times ( $t_r$ ) and the UV spectra in the extract with the peak and spectra of known standard compounds.

For quantitative estimation of gallic acid, catechin and ellagic acid regression curves of the standard for each of the compounds were developed using the same HPLC parameters that were used for extract analyses. Oleuropein, a phenolic compound not found in pecans, was used as internal standard in each run. Concentration of the phenolic compounds in extracts was calculated using regression equations and incorporating the appropriate dilution factor. Phenolic acid content in methanolic pecan extract was presented as g kg<sup>-1</sup> of defatted pecan power.

#### Fatty acid determination

The lipid extracts were saponified by the addition of 0.5 mol L<sup>-1</sup> KOH in methanol and methylated with boron trifluoride–methanol following a modification of the procedure by Morrison and Smith.<sup>27</sup> Fatty acid methyl esters were analyzed in a Varian CP 3800 gas chromatograph (Palo Alto, CA, USA) coupled with a Varian CP-8200 autosampler and a flame ionization detector (FID). A Varian FAME fused-silica capillary column (100 m × 0.25 mm, Varian CP-Select CB) was used to determine lipid profile. Oven temperature was set from 0 to 30 min at 185 °C and from 30 to 45 min at 235 °C with an increase of 20 °C min<sup>-1</sup>. FID temperature was set at 270 °C and helium, air and hydrogen flows at 1.6, 300 and 35 mL min<sup>-1</sup>, respectively. Identification of sample fatty acids was made by comparing relative retention times of FAME peaks from samples with those of standards, expressed as fatty acid content, and quantified using internal standards.

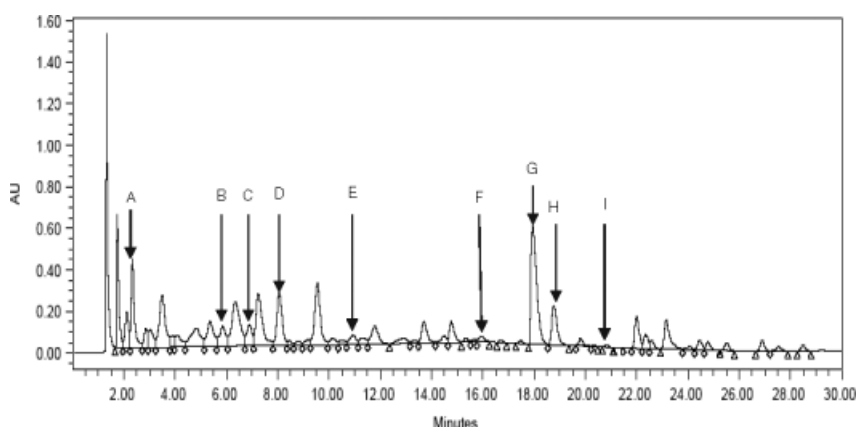
#### Statistical analysis

Three replicate extractions were carried out for each of the samples and each of the extracts was analyzed in triplicate HPLC injections. Statistical analysis on the means of triplicate experiments was carried out using the ANOVA procedure of the InStat<sup>®</sup> software, version 3.0 (GraphPad, San Diego, CA, USA). Tukey's test of significance between means was used for illustration of significance.

## RESULTS AND DISCUSSION

#### Identification of free phenolic compounds

Before investigating differences in contents of different phenolic compounds in organic *versus* conventionally grown samples of pecan kernels, a comprehensive study was conducted to identify various phenols in defatted pecan samples. A total of five 2 mL fractions were collected from chromatography on LH-20. Nine phenolic compounds were identified in the second 2 mL fraction collected from LH-20 chromatography of the pecan extract (while all the phenols identified were present in this fraction, the HPLC profile did not represent accurate quantitative levels of each compound relative to each other in total extract) by matching retention times and UV spectra on the HPLC chromatogram (Fig. 1). Phenolic compounds were quantified using remaining LH-20 fractions. The phenolic compounds that matched with the retention time and UV spectra of their respective standard compound were: gallic acid, catechol, *m*-coumaric acid, catechin, caffeic acid, epicatechin, chlorogenic acid, ellagic acid and an ellagic acid derivative. In previous reports, identification of phenolic compounds in pecan kernels had not been possible without first subjecting the extract to a hydrolysis step.<sup>11,16</sup> Our ability to identify free phenolic compounds in the extract, without a hydrolysis step, could possibly be due to the purification of the extract by LH-20 chromatography. Hydrolysis of the purified extract did not improve the results, and therefore the procedure, as described in detail in the 'Materials and methods' section, was adopted as a standard technique for analyzing all samples in this study. Of the nine phenols identified in the extract, only gallic acid, catechin and ellagic acid occurred in sufficient quantities for accurate quantitative measurements and therefore only these three compounds were evaluated for quantitative differences between organic and conventionally grown pecans.



**Figure 1.** Typical chromatogram of pecan methanolic extract after LH-20 chromatography. A: gallic acid ( $t_r = 2.33$ ;  $\lambda_{\max} = 215\,271$  nm); B: catechol ( $t_r = 5.85$ ;  $\lambda_{\max} = 211\,275$  nm); C: *m*-coumaric acid ( $t_r = 6.89$ ;  $\lambda_{\max} = 213\,277$  nm); D: catechin ( $t_r = 8.05$ ;  $\lambda_{\max} = 209\,279$  nm); E: caffeic acid ( $t_r = 11.32$ ;  $\lambda_{\max} = 216\,323$  nm); F: epicatechin ( $t_r = 15.96$ ;  $\lambda_{\max} = 207\,278$  nm); G: ellagic acid derivative ( $t_r = 17.95$ ;  $\lambda_{\max} = 253\,359$  nm); H: ellagic acid ( $t_r = 18.77$ ;  $\lambda_{\max} = 252\,366$  nm); I: chlorogenic acid ( $t_r = 20.80$ ;  $\lambda_{\max} = 218\,324$  nm).

Previously, Villarreal-Lozoya *et al.*<sup>11</sup> quantified only gallic acid and ellagic acid in their extract and trace amounts of catechins were observed. Villarreal-Lozoya *et al.*<sup>11</sup> reported levels of gallic acid and ellagic acid in pecans 10–20 times higher than those reported by Senter *et al.*<sup>16</sup> and attributed this difference to the strong alkali hydrolysis condition that they employed. It was also reasoned that very low amounts of catechin found in extracts may also be due to strong hydrolysis conditions. It is interesting to note, however, that even Senter *et al.*<sup>16</sup> employed fairly strong acid hydrolysis conditions (refluxing for two hours with 1 mol L<sup>-1</sup> HCl). Thus, three to four times higher levels reported by Senter *et al.*<sup>16</sup> (60–80 g kg<sup>-1</sup> defatted tissue) of gallic acid compared to the levels found in our study (15.9–21.3 g kg<sup>-1</sup>) could simply be due to avoidance of any hydrolysis (acid or alkali) in our analytical procedure. The results reported in this study therefore represent levels of naturally occurring free polyphenols with minimal changes through processing and extraction procedures.

Catechin and ellagic acid were the major phenolic compounds found in pecan kernels (Fig. 2), confirming what was already found by Villarreal-Lozoya *et al.*<sup>11</sup> The abundance of these compounds in kernel extracts shows that pecans contain phenolic compounds that are powerful antioxidants with many health benefits.<sup>11,19–21</sup>

#### Quantification of free phenolic compounds in organic versus conventionally grown pecans

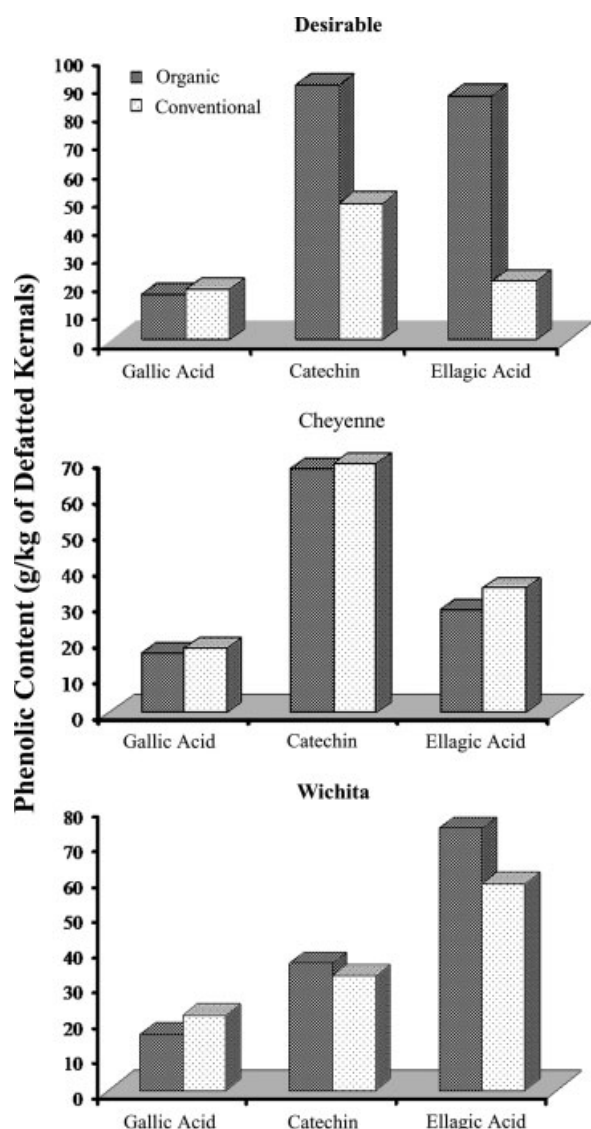
In organically grown 'Desirable', levels of health-benefiting compounds such as catechin and ellagic acid were much higher (86% and 311%, respectively) than in conventionally grown pecans

(Fig. 2); however, differences in levels of gallic acid between these treatments were small and not significant. Comparison of significance between cultivars and cultivation methods are presented in Table 2. A somewhat similar pattern of change in the phenolic compounds between organically versus conventionally grown 'Wichita' pecans was also observed but at a much smaller scale; i.e. ellagic acid was 26% higher in organic samples (Fig 2). In 'Cheyenne', differences in levels of all three phenolic acids between organically versus conventionally grown samples were small. In addition to differences between cultural practices within cultivars, significant differences between cultivars under the same cultivation practice were also observed (Table 2). Catechin levels were significantly higher in 'Desirable' and 'Cheyenne' than in 'Wichita' under both cultivation practices. For example, catechin levels in 'Desirable' and 'Cheyenne' were 60% and 46% higher, respectively, than 'Wichita' under organic cultivation. However, under conventional cultivation, catechin levels in 'Desirable' and 'Cheyenne' were only 33% and 53% higher, respectively, compared to 'Wichita'. Concerning ellagic acid, organically cultivated 'Desirable' and 'Wichita' contained higher levels of this compound (66% and 61%, respectively) than organically cultivated 'Cheyenne'. On the other hand, under conventional cultivation, 'Cheyenne' and 'Wichita' had higher levels of ellagic acid (64% and 39%, respectively) compared to 'Desirable'. Minor differences were observed in levels of gallic acid, but these differences were maintained within cultivars. No noticeable difference was observed between cultivars. These results show that growing organic pecans to increase the pool of beneficial phenolic compounds would likely depend on the cultivar used. This is consistent with earlier findings that environmental factors, in combi-

**Table 2.** Significance of difference of gallic acid, catechin and ellagic acid between varieties and cultivation methods

Gallic acid (g kg <sup>-1</sup> ± SD)	DC (17.81 ± 1.01)	DO (15.99 ± 3.92)	WC (21.31 ± 4.84)	WO (15.90 ± 3.77)	CC (17.81 ± 0.98)	CO (16.20 ± 1.25)
DC (17.81 ± 1.01)	–	NS	NS	NS	NS	NS
DO (15.99 ± 3.92)	NS	–	**	NS	NS	NS
WC (21.31 ± 4.84)	NS	**	–	**	NS	*
WO (15.90 ± 3.77)	NS	NS	**	–	NS	NS
CC (17.81 ± 0.98)	NS	NS	NS	NS	–	NS
CO (16.20 ± 1.25)	NS	NS	*	NS	NS	–
Catechin (g kg <sup>-1</sup> ± SD)	DC (48.21 ± 4.13)	DO (90.00 ± 5.12)	WC (32.54 ± 2.54)	WO (36.13 ± 11.76)	CC (69.34 ± 4.27)	CO (67.90 ± 0.64)
DC (48.21 ± 4.13)	–	***	***	***	***	***
DO (90.00 ± 5.12)	***	–	***	***	***	***
WC (32.54 ± 2.54)	***	***	–	NS	***	***
WO (36.13 ± 11.76)	***	***	NS	–	***	***
CC (69.34 ± 4.27)	***	***	***	***	–	NS
CO (67.90 ± 0.64)	***	***	***	***	NS	–
Ellagic acid (g kg <sup>-1</sup> ± SD)	DC (20.96 ± 2.95)	DO (86.21 ± 7.37)	WC (58.65 ± 4.59)	WO (74.42 ± 1.64)	CC (34.52 ± 0.75)	CO (28.59 ± 2.05)
DC (20.96 ± 2.95)	–	***	***	***	***	NS
DO (86.21 ± 7.37)	***	–	***	**	***	***
WC (58.65 ± 4.59)	***	**	–	***	***	***
WO (74.42 ± 1.64)	***	**	***	–	***	***
CC (34.52 ± 0.75)	***	***	***	***	–	NS
CO (28.59 ± 2.05)	NS	***	***	***	NS	–

Asterisks indicate significant differences at \*  $P < 0.05$ , \*\*  $P < 0.01$  and \*\*\*  $P < 0.001$ , respectively, between samples. NS indicates no significance. Samples are indicated as (DC) Desirable conventional, (DO) Desirable organic, (WC) Wichita conventional, (WO) Wichita organic, (CC) Cheyenne conventional, (CO) Cheyenne organic.



**Figure 2.** Phenolic compound composition of kernels collected from trees grown with conventional and organic cultivation methods.

nation with genetic makeup of the crop and horticultural practices, jointly determine the phytochemical makeup of nuts.<sup>28,29</sup> Furthermore, because of so many variables involved in affecting the outcome of organic farming, both increases and decreases in phenolic compounds under organic cultivation have been reported.<sup>5,30,31</sup>

#### Comparison of total oil and fatty acid composition

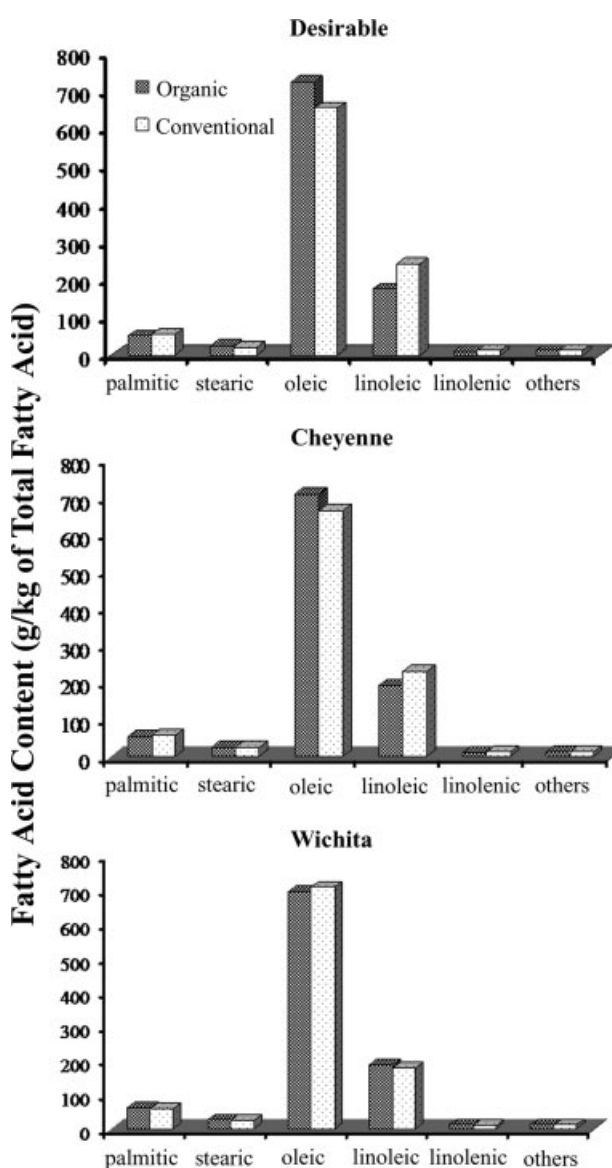
'Desirable', the same cultivar that produced substantially higher levels of phenolic compounds when grown organically (Fig. 2), also produced significantly higher amounts of oil in organically *versus* conventionally grown trees (614.3 g *versus* 535.8 g kg<sup>-1</sup> of pecan kernels, respectively) (Table 3). There were no significant differences between the two cultural practices in 'Cheyenne' or 'Wichita' (Table 3). Thus 'Desirable' appears to be the right candidate for further studies to test the effect of different kinds of organic amendments for growing organic pecan.

Profiles of individual fatty acids showed significantly higher ( $P < 0.01$ ) content of oleic acid in organically grown 'Desirable' but there was no such difference in 'Wichita' and 'Cheyenne'

**Table 3.** Weight of oil extracted from frozen 'Desirable', 'Cheyenne' and 'Wichita' pecan kernels collected from trees grown with conventional and organic cultivation methods

Cultivar	Cultivation method	Average oil weight (g kg <sup>-1</sup> ) $n = 3$
Desirable	Conventional	535.77 $\pm$ 10.46***
	Organic	614.33 $\pm$ 7.88***
Cheyenne	Conventional	551.00 $\pm$ 7.63
	Organic	559.00 $\pm$ 0.80
Wichita	Conventional	585.00 $\pm$ 32.80
	Organic	643.33 $\pm$ 36.17

Cultivars marked \*\*\* are significantly different at  $P < 0.001$ .



**Figure 3.** Fatty acid composition of oils from pecan kernels collected from trees grown with conventional and organic cultivation methods.

**Table 4.** Significance of difference of fatty acid content between varieties and cultivation methods

Palmitic (g kg <sup>-1</sup> ± SD)	DC (55.29 ± 3.84)	DO (52.18 ± 2.81)	WC (59.87 ± 1.82)	WO (62.33 ± 1.72)	CC (58.31 ± 5.25)	CO (54.71 ± 1.80)
DC (55.29 ± 3.84)	–	NS	NS	NS	NS	NS
DO (52.18 ± 2.81)	NS	–	*	**	NS	NS
WC (59.87 ± 1.82)	NS	*	–	NS	NS	NS
WO (62.33 ± 1.72)	NS	**	NS	–	NS	*
CC (58.31 ± 5.25)	NS	NS	NS	NS	–	NS
CO (54.71 ± 1.80)	NS	NS	NS	*	NS	–
Steric (g kg <sup>-1</sup> ± SD)	DC (22.01 ± 2.86)	DO (24.74 ± 1.52)	WC (26.59 ± 0.44)	WO (27.41 ± 1.62)	CC (23.47 ± 0.99)	CO (24.25 ± 2.09)
DC (22.01 ± 2.86)	–	NS	*	**	NS	NS
DO (24.74 ± 1.52)	NS	–	NS	NS	NS	NS
WC (26.59 ± 0.44)	*	NS	–	NS	NS	NS
WO (27.41 ± 1.62)	**	NS	NS	–	NS	NS
CC (23.47 ± 0.99)	NS	NS	NS	NS	–	NS
CO (24.25 ± 2.09)	NS	NS	NS	NS	NS	–
Oleic (g kg <sup>-1</sup> ± SD)	DC (656.60 ± 32.59)	DO (725.31 ± 31.95)	WC (711.33 ± 23.05)	WO (608.24 ± 3.31)	CC (665.34 ± 11.07)	CO (709.90 ± 12.77)
DC (656.60 ± 32.59)	–	**	*	NS	NS	*
DO (725.31 ± 31.95)	**	–	NS	NS	*	NS
WC (711.33 ± 23.05)	*	NS	–	MS	NS	NS
WO (608.24 ± 3.31)	NS	NS	NS	–	NS	NS
CC (665.34 ± 11.07)	NS	*	NS	NS	–	NS
CO (709.90 ± 12.77)	*	NS	NS	NS	NS	–
Linoleic (g kg <sup>-1</sup> ± SD)	DC (241.67 ± 29.68)	DO (175.31 ± 28.00)	WC (179.36 ± 21.75)	WO (189.29 ± 3.59)	CC (229.20 ± 6.21)	CO (190.29 ± 10.80)
DC (241.67 ± 29.68)	–	**	***	*	NS	*
DO (175.31 ± 28.00)	**	–	NS	NS	*	NS
WC (179.36 ± 21.75)	**	NS	–	NS	*	NS
WO (189.29 ± 3.59)	*	NS	NS	–	NS	NS
CC (229.20 ± 6.21)	NS	*	*	NS	–	NS
CO (190.29 ± 10.80)	*	NS	NS	NS	NS	–
Linolenic (g kg <sup>-1</sup> ± SD)	DC (11.44 ± 1.89)	DO (9.97 ± 0.28)	WC (10.78 ± 0.24)	WO (11.70 ± 1.33)	CC (11.18 ± 0.69)	CO (8.26 ± 0.31)
DC (11.44 ± 1.89)	–	NS	NS	NS	NS	**
DO (9.97 ± 0.28)	NS	–	NS	NS	NS	NS
WC (10.78 ± 0.24)	NS	NS	–	NS	NS	*
WO (11.70 ± 1.33)	NS	NS	NS	–	NS	**
CC (11.18 ± 0.69)	NS	NS	NS	NS	–	**
CO (8.26 ± 0.31)	**	NS	*	**	**	–

Asterisks indicate significant differences at \*  $P < 0.05$ , \*\*  $P 0.01$  and \*\*\*  $P 0.001$ , respectively, between samples. NS indicates no significance.

(Table 4). (Concerning differences between cultivars, 'Wichita' grown conventionally showed higher levels of oleic acid than conventionally grown 'Desirable' (Table 4).) Both 'Desirable' and 'Cheyenne' cultivars also showed lesser amounts of linoleic acid under organic cultivation practices, but the difference was only significant for 'Desirable' cultivar (Fig. 3). These results are consistent with the findings of Gutierrez *et al.*,<sup>25</sup> who found higher levels of oleic acid and lower levels of linoleic acid in organically produced olive oils. On the other hand, Peretti *et al.*<sup>32</sup> reported that production methods does not affect fatty acid composition, while Samman *et al.*<sup>33</sup> observed no consistent overall trend between fatty acid composition of organic and conventional oils. This brings us back to the question of the cultivar used in the

study, and as noted above it seems necessary first to identify a responsive cultivar and then maximize the beneficial health effects of organic farming through systematically studying various organic amendments.

## CONCLUSIONS

Analysis of phenolic compounds and fatty acid composition in organically and conventionally grown 'Cheyenne', 'Desirable' and 'Wichita' pecans showed that organically grown 'Desirable' produced higher levels of health-benefiting phenolic compounds (e.g. catechins and ellagic acid) and fatty acid (oleic acid). It is concluded that cultivar differences can influence the results of

studies on organic systems aimed to evaluate the effect of specific cultural practices. To obtain consistent beneficial results from organic farming it appears important to identify the cultivars that respond to organic cultural practices and then optimize the health benefits in that cultivar by systematically testing different organic amendments.

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